Low Power Design Essentials

Series on Integrated Circuits and Systems

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Continued after index

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Low Power Design Essentials

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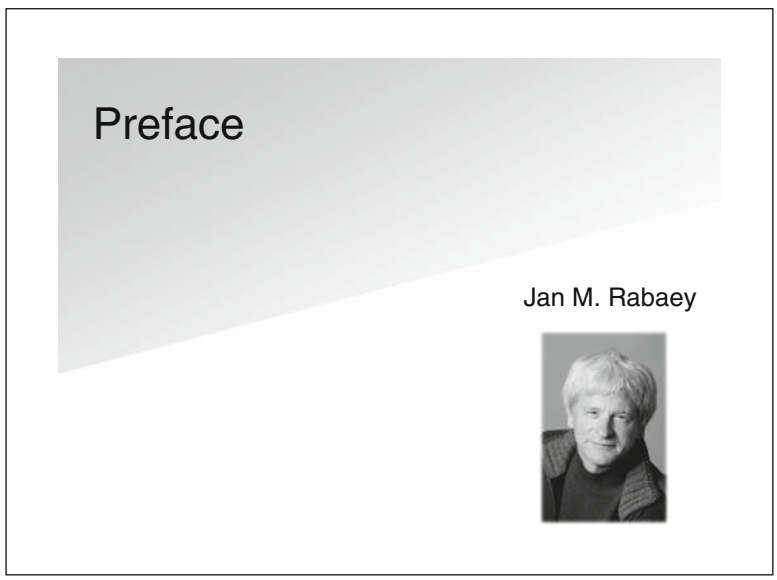
To Kathelijin
For so many years, my true source of support and motivation.

To My Parents
While I lost you both in the past two years, you still inspire me to reach ever further.

Preface



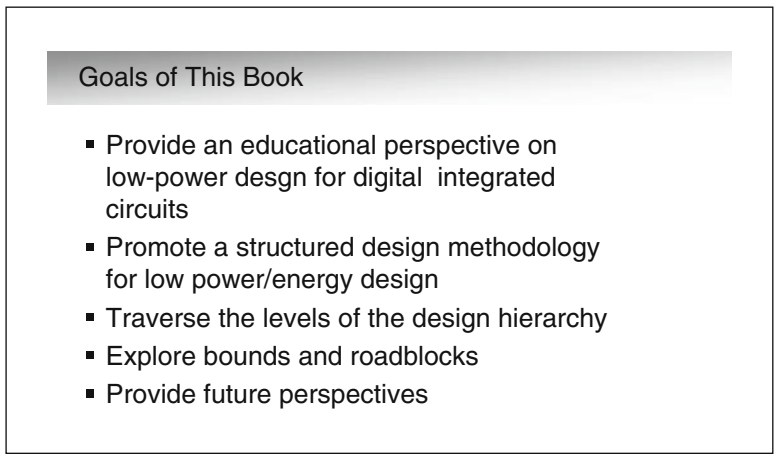
Slide 0.1

Welcome to this book titled "Low Power Design Essentials". (A somewhat more accurate title for the book would be "Low Power Digital Design Essentials", as virtually all of the material is focused on the digital integrated-circuit design domain.)

In recent years, power and energy have become one of the most compelling issues in the design of digital circuits. On one end, power has put a severe limitation on how fast we can run our circuits; at the other end, energy reduction techniques have enabled us to build ubiquitous mobile devices that can run on a single battery charge for an exceedingly long time.

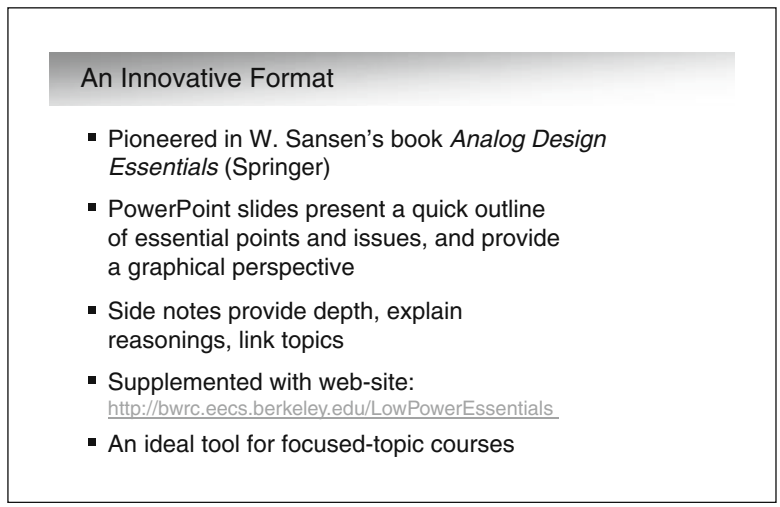
Slide 0.2

You may wonder why there is a need for yet another book on low-power design, as there are quite a number of those already on the market (some of them co-authored by myself). The answer is quite simple: all these books are edited volumes, and target the professional who is already somewhat versed in the main topics of design for power or energy. With these topics becoming one of the most compelling issues in design today, it is my opinion that it is time for a book with *an educational approach*. This means building up from the basics, and exposing the different subjects in a rigorous and methodological way with consistent use of notations and definitions. Concepts are illustrated with examples using state-of-the-art technologies (90 nm and below). The book is primarily intended for use in short-to-medium length courses on low-power design. However, the format also should work well for the working professional, who wants to update her/himself on low-power design in a self-learning manner.



This preface also presents an opportunity for me to address an issue that has been daunting low-power design for a while. Many people in the field seem to think that it is just a "bag of tricks" applied in a somewhat ad hoc fashion, that it needs a guru to get to the bottom, and that the *concept of a low-power methodology* is somewhat an oxymoron. In fact, in recent years researchers and developers have demonstrated that this need not be the case at all. One of the most important realizations over the past years is that minimum-energy design, though interesting, is not what we truly are pursuing. In general, we design in an energy–delay trade-off space, where we try to find design with the lowest energy for a given performance, or vice versa. A number of optimization and design exploration tools can be constructed that help us to traverse this trade-off space in an informed fashion, and this at all levels of the design hierarchy.

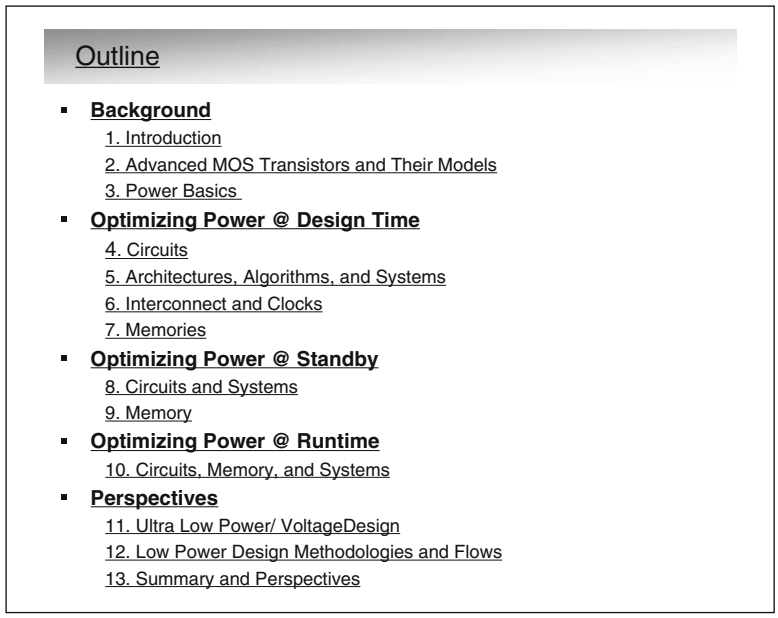
In addition to adhering to such a methodology throughout the text, we are also investigating the main *roadblocks* that we have to overcome in the coming decades if we want to keep reducing the energy per operation. This naturally leads to the question of what the *physical limits* of energy scaling might be. Wherever possible, we also venture some perspectives on the future.



Slide 0.3

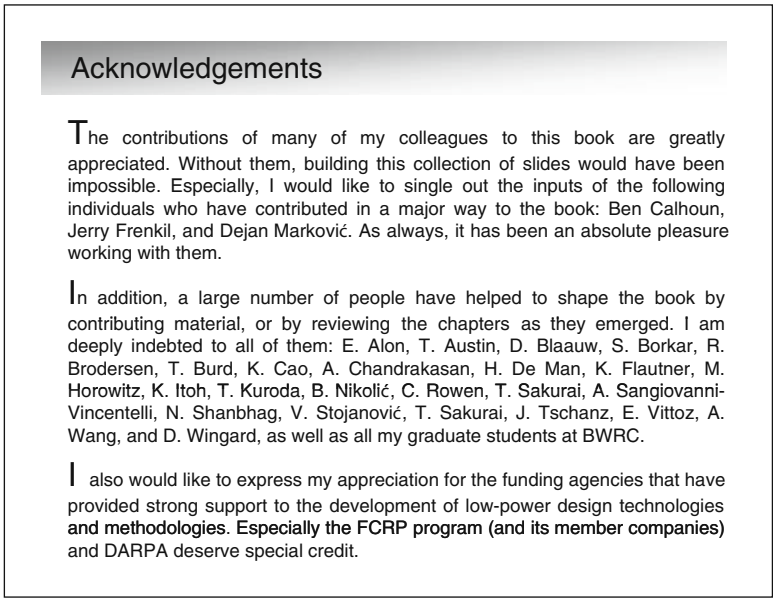
Already in this preface, you observe the somewhat unorthodox approach the book is taking. Rather than choosing the traditional approach of a lengthy continuous text, occasionally interspersed with some figures, we use the reverse approach: graphics first, text as a side note. In my experience, a single figure does a lot more to convey a message than a page of text ("A picture is worth a 1000 words"). This approach was pioneered by Willy Sansen in his book *Analog Design Essentials* (also published by Springer). The first time I saw the book, I was immediately captivated by the idea. The more I looked at it, the more I liked it. Hence this book .... When browsing through it, you will notice that the slides and the notes play entirely

different roles. Another advantage of the format is that the educator has basically all the lecturing material in her/his hands rightaway. Besides distributing the slideware freely, we also offer additional material and tools on the web-site of the book.



Slide 0.4

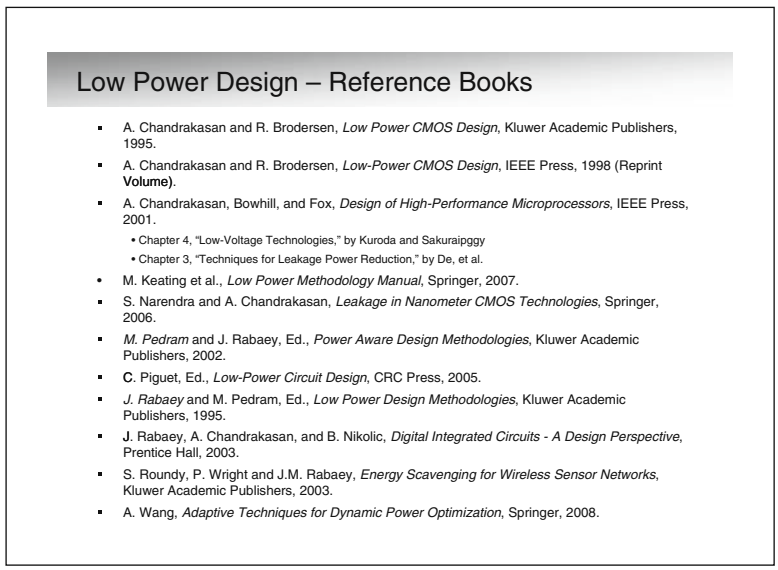
The outline of the book proceeds as follows: After first establishing the basics, we proceed to address power optimization in three different operational modes: design time, standby time, and run time. The techniques used in each of these modes differ considerably. Observe that we treat dynamic and static power simultaneously throughout the text – in today's semiconductor technology, leakage power is virtually on par with switching power. Hence separating them does not make much sense. In fact, a better design is often obtained if the two are carefully balanced. Finally, the text concludes with a number of general topics such as design tools, limits on power, and some future projections.

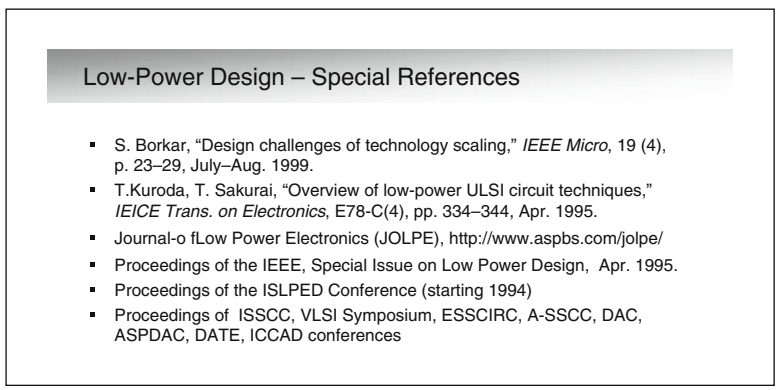


Slide 0.5

Putting a book like this together without help is virtually impossible, and a couple of words of thanks and appreciation are in order. First and foremost, I am deeply indebted to Ben Calhoun, Jerry Frenkil, Dejan Marković, and Bora Nikolić for their help and co-authorship of some of the chapters. In addition, a long list of people have helped in providing the basic slideware used in the text, and in reviewing the

earlier drafts of the book. Special gratitude goes to a number of folks who have shaped the low-power design technology world in a tremendous way – and as a result have contributed enormously to this book: Bob Brodersen, Anantha Chandrakasan, Tadahiro Kuroda, Takayasu Sakurai, Shekhar Borkar, and Vivek De. Working with them over the past decade(s) has been a great pleasure and a truly exciting experience!





Slide 0.6–0.7

Every chapter in the book is concluded with a set of references supporting the material presented in the chapter. For those of you who are truly enamored with the subject of low-power design, these slides enumerate a number of general reference works, overview papers, and visionary presentations on the topic.

I personally had a wonderful and truly enlightening time putting this material together while traversing Europe during my sabbatical in the spring of 2007. I hope you will enjoy it as well.

Jan M. Rabaey, Berkeley, CA

Contents